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EFFECT OF RELATIVE HUMIDITY ON ANTI-STATIC PROPERTIES OF NON-METALLIC MINE MATERIALS

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by

N.K. Sarin*

ABSTRACT

This report points out that a review is needed of the existing standards for the evaluation of anti-static properties of non-metallic materials intended for mines, in order to make these more compatible with the Canadian mine environment.

The CEAL version of the European standard EN50014 was employed for convenience in testing several flexible ventilation duct materials under controlled humidity conditions within ±5% of the desired setting. It is concluded that the electrical surface resistance of these materials reduces with an increase in relative humidity, while other variables remain constant.

The author recommends 45 ±2% relative humidity for the test environment as opposed to 65% ±5% specified in the National Coal Board (NCB) specification 158/1980. This is intended to increase the margin of safety in Canadian underground gassy mines irrespective of the testing procedure employed for the evaluation of such materials.

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ÉTUDE DE L'EFFET DE L'HUMIDITÉ RELATIVE SUR LES PROPRIÉTÉS ANTI-STATIQUES DES MATÉRIAUX MINIERS NON-MÉTALLIQUES

par

N.K. Sarin*

RÉSUMÉ

Ce rapport souligne la nécessité d'effectuer une révision des normes actuelles utilisées pour évaluer les propriétés anti-statiques des matériaux non-métalliques destinés aux mines. Cette révision aurait pour but de rendre ces normes plus compatibles avec l'environnement minier canadien.

La norme du Laboratoire canadien de recherche sur les atmosphères explosives (LCRAE) équivalant à la norme européenne EN50014 a été utilisée par souci de commodité afin d'effectuer l'essai de plusieurs matériaux composant les gaines de ventilation flexibles, dans des conditions où l'humidité est contrôlée à ±5 % de la prise désirée. On en est arrivé à la conclusion qu'on obtient une réduction de la résistance de la surface électrique de ces matériaux en augmentant l'humidité relative, alors que les autres variables demeurent constantes.

L'auteur recommande 45 ±2 % d'humidité relative dans le milieu où les essais sont effectués contrairement à 65 % ±5 % déterminé par le National Coal Board (NCB) spécification 158/1980. Cette recommandation a pour but d'augmenter la marge de sécurité dans les mines souterraines grisouteuses canadiennes, sans tenir compte de la procédure employée lors des essais pour évaluer les matériaux miniers.

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INTRODUCTION

Accidental discharge of electrostatic energy from non metallic materials could cause explosion and fire in coal and other gassy mines. Mine ventilation ducts, conveyor belts, V-belts etc. are made from PVC and rubber compounds mixed with fire-retardant materials. Due to friction of contacting media, electrostatic charges build up on the surface of these products. This is potentially dangerous unless means are provided to prevent the existence of such changes, either by using anti-static materials, or by using suitable grounding techniques inside the mine, or preferably both (2).

For the evaluation of electrostatic conductivity or electrical surface resistance several standards are in existence (1). CEAL versions of NCB specification 158/1980 for flexible materials and a European standard EN50014 for rigid and irregular shaped products were used; however these tests have been conducted in an uncontrolled environment at CEAL. The relative humidity in the laboratory varies considerably from summer to winter. According to NCB specification 158/1980, it is mandatory to maintain 65% ±5% relative humidity in the test environment. Canadian mines are generally drier than U.K. mines and, therefore, a different test criteria must be investigated. The worst conditions exist during the driest winter months. Generally, materials meeting the test criteria in relatively drier conditions would also qualify for acceptance in relatively wet environments i.e., 65 ±5% humidity levels. This approach is suitable during the dry winter months, however, some concern remains with tests carried out under high humidity conditions in summer. Therefore, the necessity to acquire an environmental control chamber for this purpose became obvious.

Some clients disagreed with the use of variable ambient test conditions at CEAL, and insisted upon the use of 65 ±5% relative humidity conditions. Consequently, to assist in the formulation of a new test criteria which are more compatible with the Canadian underground mines that have explosive atmospheres, it is important to study the variation of electrical surface resistance with respect to relative humidity.

Due to lack of proper facilities and precise control on other variables, such as sample soaking times under a constant humidity level and testing temperature, we regard this study as only a preliminary investigation.

TEST PROCEDURE

An environmental humidity control chamber at the Department of National Defence Quality Engineering and Test Establishment (QETE), located in Hull, was used for initial trial runs at 22°C and 65% relative humidity in accordance with NCB specification 158/1980. This preliminary work was done on 18 different samples of brattice cloth which were earlier tested for certification in an uncontrolled environment at CEAL. These are listed in Table 1.

Samples were conditioned for 24 h at the required humidity level before testing commenced at QETE. It was considered, however, that, although the QETE facility had very reliable equipment, it was impractical to transport all the testing gear from CEAL and to use the QETE facility at our own convenience. Therefore, as an alternate, a domestic humidifier in an enclosed room was employed at CEAL to generate desired humidity levels within ±5% tolerance. Also, the room temperature varied between 20°C to 24°C on different days. The humidity levels were checked with a wet and dry bulb hygrometer before testing each material.

All of the 18 test samples were retested several times under different humidity settings using the CEAL version of the European test standard En51004 (1) for convenience and simplicity. The results are listed in Table 2.

Prior to testing, the samples were soaked for at least 24 h at the maximum relative humidity obtainable between 65 and 75%. It was impossible, therefore, to maintain steady humidity levels during sample soaking periods. It was possible, however, to reduce the humidity to the desired testing levels by switching off the humidifier and waiting for a while before commencing the tests.

The instrument used for recording the electrical surface resistance was a Megger unit manufactured by Evershed and Vignol Ltd, U.K. This has a fixed applied potential of 250V d.c. with a scale ranging between 1-10,000 MΩ (Megohms). Due to the analog nature of the instrument the scale divisions were not uniform and the precision of readings was limited to approximately ±2%, ±5% and ±10% for the ranges of 1-1000 MΩ, 1000-2000 MΩ, and 2000-10,000 MΩ, respectively.

For details of the testing procedures, please consult the report in reference #1.

A brief survey of Canadian coal mines was carried out to determine actual humidity levels encountered during the driest winter months. Heating the cold air entering mines causes mine humidity to be reduced. A summary of the survey is listed in Appendix "A".

OBSERVATIONS AND DISCUSSIONS

Appendix "A" contains summaries of the results of the investigations done at QETE and at CEAL under two sets of humidity conditions. It is apparent, from these data, that electrical surface resistance in most of the materials has an inverse relationship to the level of relative humidity in the test environment. The difference in the magnitude of the resistances is more pronounced outside the middle range of the instrument scale i.e., between 100-1000M MΩ. Some inaccuracies are inherent due to lack of precision in the analog instrument; however, a digital instrument was not available at the time of this investigation.

Appendix "B" relates to the attached graph of relative humidity (R.H.) vs Electrical (surface) resistance, obtained by using the CEAL version of the European test standard EN51004 (1). This method was chosen for simplicity and to prevent the possibility of errors caused by using a liquid contact agent as is done in the case of the NCB test procedure (4).

It is evident from Fig. 1 that some materials are influenced by R.H. much more than others. The conveyor belt material with rubber compounds, as indicated by samples #2,3, and 6 in particular, have shown relatively less sensitivity to the changes in humidity levels. Their ranges of electrical resistances, however, is well within the acceptable maximum limit of 120 MΩ used by CEAL for ventilation materials. On the other hand, brattice cloth and flexible textile materials coated with plastic materials or similar compounds are very sensitive to humidity levels; i.e., electrical resistances decrease sharply with an increase in humidity levels from 20% to 40%. Nonetheless, it is interesting to observe that most of the materials tested would fall within the acceptable limit of electrical surface resistance of 300 MΩ if tested in an environment exceeding 35% relative humidity.

Canadian gassy mines are drier than similar mines in the U.K., (where the NCB specification originated), calling for 65 ±5% humidity levels for test

purposes. Data collected from several coal mines in Canada suggest that humidity levels can drop to 35% in some situations during cold winter months. Although humidity levels near the working faces have been found to be higher than 50%, we should not ignore the possibility of the presence of explosive gas in return airways. As it is possible to encounter environments having relative humidity less than 65%, it is certainly desirable to reduce this requirement for CEAL certification purposes. In the opinion of the author, a level of 45 ±2% relative humidity appears appropriate for testing electrostatic properties on non-metallic mine materials. A tolerance of ±2% is chosen to conform with the accuracy limits of commercially available humidity control chambers at reasonable cost.

"Other than the impact of relative humidity, it is also known that polymeric materials in industrial use do not have clean surfaces and the level of electrification is often influenced by surface contamination, impurities or absorbed materials rather than the basic chemical constitution of the solid" (3). For this reason, special care was taken in treating the test surfaces with dry powder, washing these with distilled water, and drying the same prior to carrying out each test. However, it is believed that variables such as material conditioning time, environmental temperature, atmospheric pressure and dust particles could have some effect on the electrostatic properties of materials considered in this investigation. Care has been taken to keep these variables as constant as possible.

The very fact that an upper limit is imposed on the electrical surface resistance of non-metallic mine materials implies that these materials must be at least partially conductive to allow the discharge of the electrostatic energy before buildup to dangerous levels. The rate of discharge of the energy may influence the permissible energy buildup and, consequently, the limit on the allowable electrical surface resistance. Also, the minimum energy required to ignite an explosive mine atmosphere could be used to predict the maximum allowable electrical surface resistance for the subject materials. Detailed analyses of these considerations, however, are outside of the scope of this report.

The Canadian Standard Association (CSA) subcommittee for CSA draft standard M422, "Fire-Resistant and Antistatic Conveyor Belting" has tentatively agreed to use 50 ±5% relative humidity for evaluation of electrostatic

properties using the test prescribed in the ISO standard 284 (4). This decision is based on the consideration that, in Canadian mines, 50% would provide a better safety margin than the 70% specified in the CEAL report ERP/MRL 80-21 (5). The CSA committee should be advised of the present investigation and the results of the survey on relative humidity in Canadian mines, in order to seek their support. Besides, a standardization of the test environment for all types of non-metallic materials including conveyor belts and ventilation duct materials for mines would be more logical and desirable from a practical point of view.

Experience at CEAL has indicated that some products have a very thin layer of anti-static compounds sprayed on them. Once this layer is worn out, the same material would not meet the certification requirements. This is particularly true for the flexible brattice cloth or polyethylene sheets employed in boreholes for charging explosives. Obviously, then, the endurance of anti-static compounds sprayed on insulated materials must also be questioned. This would suggest that prior to evaluation of anti-static properties of mine materials, their surfaces may be treated with mild powder-blasting for some duration in order to simulate normal wear of the products in a rugged mining environment. This approach would encourage manufacturers to rely more on impregnating anti-static compounds throughout the basic material of the products rather than seeking temporary solutions to meet the present certification requirements at CEAL.

A rather disturbing observation of Fig. 1 indicates that samples #5 and 6 have behaved in reverse manner, i.e., their surface resistances went up at 65% relative humidity. However, the magnitudes are under 1 MΩ and are well within the acceptable limit of 120 MΩ. The only explanation for this anomaly could be an inherent inaccuracy of the recording instrument at the lower range because all other samples having resistance magnitudes between 10-1000 MΩ range behaved in a consistent manner, i.e., their resistances are inversely related to the relative humidity in the test environment.

CONCLUSIONS

It is concluded that the relative humidity of the test environment has a very significant influence on electrostatic properties of non-metallic materials. Certification testing employing humidity levels above 50% do not

cover the worst possible situations in Canadian mines. Therefore appropriate changes in the CEAL test criteria for certification of mine materials is essential.

RECOMMENDATIONS

1. A relative humidity level of 45 ±2% should be used for evaluation of electrostic properties in non-metallic materials regardless of the test standard employed for CEAL certification requirements.
2. A controlled humidity chamber should be provided for conditioning of samples under a stable environment for the prescribed duration prior to conducting the tests. This is to assist in generating more consistent and repeatable results.
3. Additional studies should be carried out to investigate the influence of material conditioning time, atmospheric temperature, and dust particles on the anti-static properties of non-metallic mine materials.
4. Some consideration should be given to investigation of the minimum energy required to ignite explosive mixtures with a view to establishing safe levels of electrostatic energy build up on various mine materials. This could lead to confirmation or change of the existing limit on electric surface resistance used by CEAL for certification of mine materials.
5. The endurance of anti-static compounds sprayed on the surface of some ventilation materials should be investigated using powder-blasting prior to re-evaluation of the anti-static properties. This may assist in revealing a safe life for anti-static compounds and may also help in the formulation of new certification requirements for such products.
6. A digital instrument with a range of 0-2000 MΩ should be employed in future investigations in order to minimize the inaccuracies attributable to such instrumentation.

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Table 1 - Electrical (surface) resistance using NCB specification 158/1980 flexible ventilation duct materials

Sr #	Sample code	*QETE Labs, Hull Humidity: 65% ±2% Temp: 22°C	**CEAL Labs Humidity: <40% Temp: 18-25°C
1	44 PI	100 MΩ	100-200 MΩ
2	48 CB(S)	5000 MΩ	∞ MΩ
3	PI(G)	5000 MΩ	∞ MΩ
4	49 SF	200-380 MΩ	230-460 MΩ
5	51 ME	260 MΩ	3000-4000 MΩ
6	52 ME	4 MΩ	112 MΩ
	55 SF	475-500 MΩ	170-200 MΩ
7	56 SF	375-900 MΩ	500-550 MΩ
8	57 SF	135-160 MΩ	408-418 MΩ
Δ9	58 DP	4000 MΩ	No test
Δ10	59 DP	5000 MΩ	No test
Δ11	61 DP	5000 MΩ	No test
12	63 ME	35-50 MΩ	540 MΩ
13	64 ME	32-40 MΩ	530 MΩ
14	65 ME	.05 MΩ	20 MΩ
15	66 BC	1800 MΩ	4000-00 MΩ
16	67 BC	2000 MΩ	4000-4250 MΩ
17	68 BC	3000 MΩ	3250-4000 MΩ
18	69 DP	5000 MΩ	∞ MΩ

Note: *1. Samples were soaked in 65% humidity at QETE labs for 24 h before testing.

**2. Testing at CEAL Labs were carried out for product certification during various times and under variable humidity conditions generally under 40% level.

3. Samples 9, 10 and 11 were not tested for anti-static as these materials had failed flammability criteria necessary for certification.

4. At least 3 samples were tested on both sides of the same materials and at least 6 readings were taken for each level of relative humidity. Some values shown indicate a range of readings and the single figures indicate an average value.

Table 2 - Electrical (surface) resistance using European Standard 51004

Non-Metallic Materials

SR #	CEAL code	Relative humidity 25 ±5%	40 ±5%	65 ±5%	Units
1	#55 BC	770 (134)	54 (14)	8 (5)	MΩ
2	Y-CB	36 (14)	19 (9)	17 (5)	MΩ
3	U-CB	160 (54)	52 (26)	14 (4)	MΩ
4	#73 BC	470 (37)	158 (13)	33 (7)	MΩ
5	#30 BC	34 (9)	36 (11)	128 (67)	KΩ
6	M-CB	255 (37)	128 (50)	217 (103)	KΩ
7	#72-BC	510 (17)	225 (48)	15 (5)	MΩ
8	#65	760 (98)	122 (52)	55 (10)	MΩ

Note: 1. Values shown in brackets () represent standard deviation, σ, of several readings taken under a particular test condition and the adjoining numbers on the left are average resistances recorded at CEAL.

2. Samples 2, 3, and 6 are conveyor belt materials and the remaining are flexible brattice cloth intended for ventilation duct materials.

3. Each test was performed on a separate specimen of the same material.

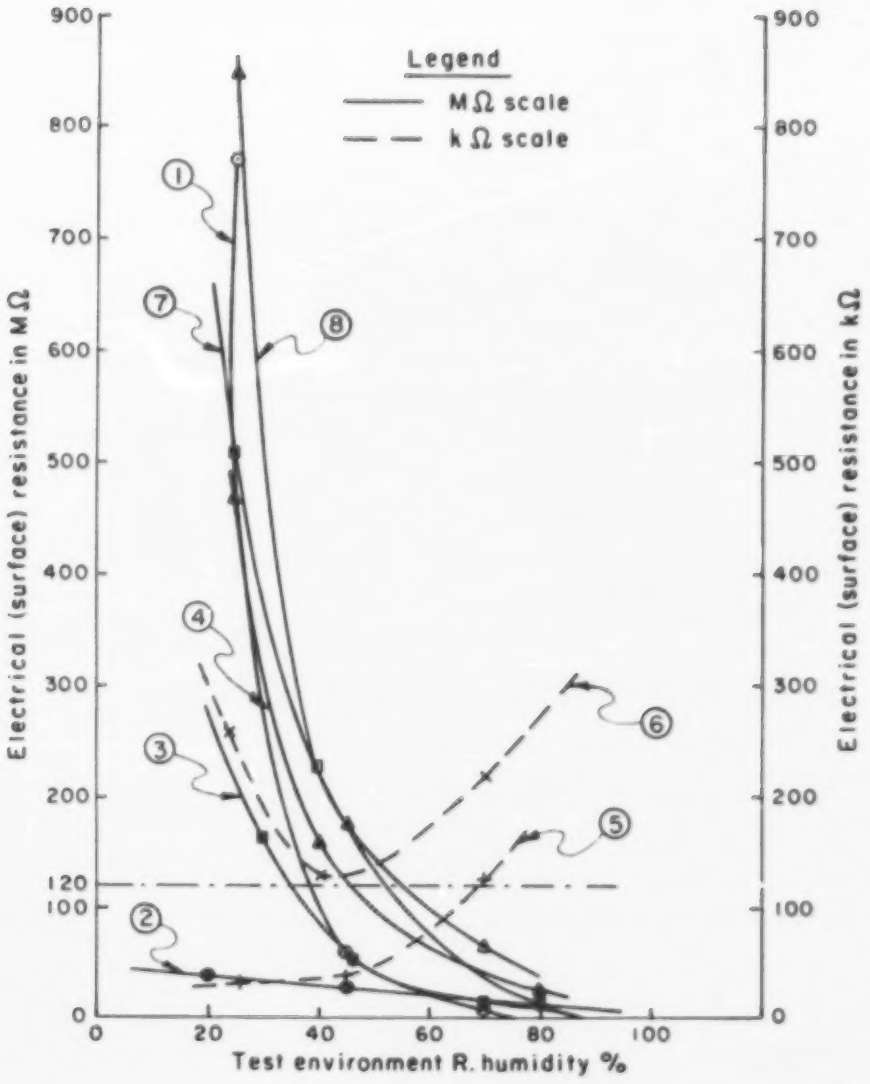

Fig. 1 - Relative humidity vs electrical resistance

Fig. 2 - Test layout, NCB Method

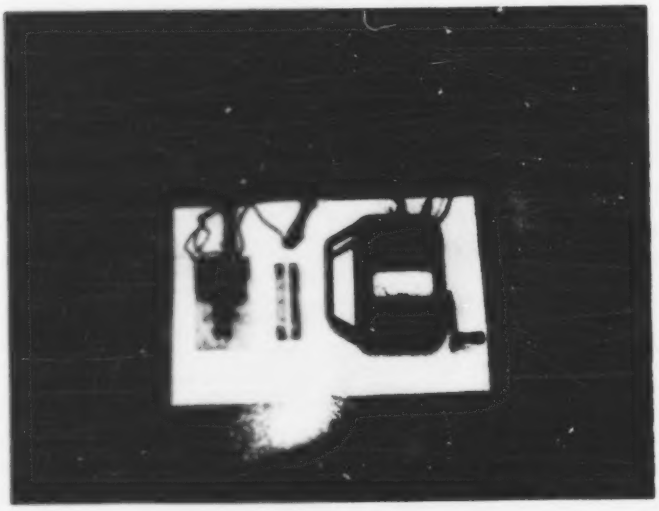

Fig. 3 - Test layout, European Method

APPENDIX - "A"

Table 3 - Survey of relative humidity in Canadian gassy mines

Source	Reading date	Mine	Location	Ambient Temperature	Lowest relative humidity
Westar Mining	Nov. 83 to	All mines	Near face	8.5°C	60%
Sparwood, B.C.	Feb. 1, 84				
Smoky River Coal	Feb. 3, 84	No. 9A-4	#2 entry 300' from surface	27°C	35%
Grande Cache, Alberta			#2 entry 700' from surface	7°C	60%
			#3 entry return way 200' from surface	12°C	63%
	Nov. 14, 84	No. 9B-4	#5 entry intake airway 500' from surface	-7°C	54%
			#6 entry intake airway 600' from surface	6°C	48%
Cape Breton	Jan. 31, 84	No. 26 Colliery	30 meters from face	N/A	66%
Development Corp. N.S.	Feb. 27, 84	No. 26 Colliery	30 meters from face	N/A	50%
	March 12, 84	No. 26 Colliery	30 meters from face	N/A	60%
	March 14, 84	Lingan Colliery	30 meters from face	N/A	71%
	March 28, 84	Lingan Colliery	30 meters from face	N/A	72%
	April 11, 84	Lingan Colliery	30 meters from face	N/A	70%
Cape Breton	Jan. 26, 83	Cape Breton Coal			
Coal Research Labs.		No. 26 Colliery	14(S)	18°C	53%